TRANSFORMING WASTE PAPER INTO SUSTAINABLE BEE WAX WRAPS.

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Abstract-Plastic pollution has become a major environmental concern, necessitating sustainable alternatives for food packaging. This study explores the development of beeswax wraps using waste paper as an eco-friendly substitute for plastic wraps. Waste paper is processed into pulp, treated with natural antimicrobial agents like neem and turmeric, and reinforced with starch adhesive. The resulting paper is then coated with beeswax to improve flexibility, durability, and water resistance. Various physical and chemical tests, including flexibility, adhesion, biodegradability, and antimicrobial effectiveness, are conducted to evaluate the wraps' performance. The study aims to provide a cost-effective and biodegradable alternative to plastic wraps, promoting waste reduction and sustainability.

https://ucanr.edu/blogs/preservation-notes/article/

Keywords: Beeswax wraps, waste paper recycling, sustainable packaging, biodegradable food wrap, plastic alternative, antimicrobial properties.

I. INTRODUCTION

1.1. Background

Plastic food wraps contribute significantly to global pollution due to their non-biodegradable nature. Beeswax wraps have emerged as an eco-friendly alternative, but traditional production relies on fabric, increasing costs and resource use. This research focuses on repurposing waste paper into beeswax wraps, offering a low-cost and sustainable packaging solution. The study aims to develop, test, and evaluate the feasibility of waste paper-based beeswax wraps.
https://ideaexchange.uakron.edu/honors_research_projects/1697/

1.2. Problem Statement

Plastic wraps are widely used for food preservation but pose environmental and health risks due to their slow degradation and potential chemical leaching. Although beeswax wraps are a sustainable alternative, fabric-based production is resource-intensive. Waste paper, an abundant and often discarded material , can be repurposed for sustainable food packaging.
However, ensuring its durability, flexibility, and antimicrobial properties remains a challenge. This study seeks to address these issues by developing and evaluating waste paper-based beeswax wraps.

1.3. Research Objectives

The primary objective of this research is to:
1. To evaluate the feasibility of converting waste paper into reusable and sustainable beeswax wraps.
2. To analyze the impact of neem and turmeric as natural antimicrobial agents in the recycled paper wraps.
3. To optimize the formulation of starch-based adhesives for enhancing paper strength and flexibility.
4. To assess the physical, mechanical, and barrier properties (e.g., water resistance, durability, and flexibility) of the beeswax-coated recycled paper.
5. To compare the effectiveness of the developed beeswax wraps with commercially available alternatives in terms of sustainability and performance.
6. To explore the biodegradability and environmental benefits of the final product compared to traditional plastic wraps.
7. To investigate consumer acceptance and market potential for beeswax wraps made from waste paper.

II.LITERATURE REVIEW

1. Antimicrobial Properties of Beeswax Wraps: Beeswax has been recognized for its natural antimicrobial properties, which can inhibit the growth of various bacteria and fungi. A study published in the Journal of Microbiology, Biotechnology and Food Sciences demonstrated that beeswax wraps significantly reduced the viable cell count. The neem and turmeric adds naturally into packing materials . So it enhances efficiency more and demonstrate antifungal .

Integration of Neem and Turmeric for Enhanced Antimicrobial Activity: Incorporating natural additives like neem and turmeric into packaging materials has shown promise in enhancing antimicrobial efficacy. Research published in *Antibiotics* investigated composite polyethylene materials infused with neem and turmeric, revealing reduced proliferation of pathogens such as *Escherichia coli*, *Staphylococcus aureus*, and *Candida albicans*. Notably, turmeric exhibited greater effectiveness against *E. coli*, while neem demonstrated superior antifungal activity against *C.* https://pubmed.ncbi.nlm.nih.gov/33266277/

Recycling Waste Paper for Sustainable Packaging: The concept of recycling waste paper into functional packaging materials is gaining traction as a sustainable alternative to plastic. Innovations in this area include the development of recyclable coatings for paper products to enhance properties like water resistance and durability. For instance, a study explored the utilization of marine and agro-waste materials, such as neem extract, in packaging, highlighting their potential in extending the shelf life of food products and reducing microbial contamination. https://www.sciencedirect.com/science/article/abs/pii/S0141813023049371

Industry Adoption of Sustainable Packaging Solutions: Major companies are transitioning to sustainable packaging to reduce environmental impact. For example, Nestlé has shifted to recyclable waxed paper for Quality Street chocolates, aiming to prevent two billion wrappers annually from ending up in landfills. This move reflects a broader industry trend towards adopting eco-friendly packaging solutions.

2. Mechanical and Physical Properties

The durability, utility, and performance of beeswax-coated recycled paper wraps, a sustainable substitute for plastic wraps, are also mostly a function of their physical and mechanical properties. Because it is tough and has mechanical characteristics like tensile strength, toughness, and tear resistance, the wrap will not deform or tear. Because the wrap has tensile strength, the wrap can be stretched and assume the shapes of other foods, and because the wrap is highly resistant to rips, this also implies that the wrap will not incorrectly tear when being applied. The wrap should be flexible and elastic in nature so that it can simplify the life of the user by wrapping around food containers or other objects easily without slipping off. Water resistance and hydrophobicity are required for water exclusion, food freshness, and prevention of spoilage. Turmeric and neem provide antimicrobial activity that prevents bacterial and fungal growth and thus enhances shelf life of covered food.

Air permeability of the cover provides room for aeration without building up excess moisture yet maintaining food freshness. Besides, grease and oil resistance renders fat-rich foods safe, and therefore the wrap will not spoil when there are oils. The fact that the wraps are biodegradable and compostable implies that one can eat them in an eco-friendly way without damaging the environment because they naturally dissolve. Thermal stability, finally, allows one to maintain wraps under changing conditions where they are able to resist temperature changes.

3. Environmental and Economic Considerations

Beeswax-coated recycled paper wraps innovation is also affordable and environmentally friendly. Environmentally, the business avoids wastage through recycling used paper that would otherwise accumulate into landfill and logging. Through preventing the application of single-use plastic wraps, the innovation saves on plastic pollution and reduces the carbon footprint of plastic production and disposal. Additionally, the biodegradable characteristics of the wraps make them biodegradable, without damaging the environment in the long run. The use of turmeric and neem makes it more sustainable as such natural products do not introduce harmful chemicals into the environment. Economically, beeswax-coated recycled paper wraps production involves a cost-effective option compared to commercially utilized plastic wraps. Waste paper as raw material has the effect of lowering the cost to bring this to consumers and businesses as well to enjoy. Additionally, production processes involve renewable and domestic resources like beeswax, neem, and turmeric that can be useful to local farmers and beekeepers. In addition, the project offers micro-enterprise entrepreneurial opportunities, wherein communities or individuals can initiate sustainable enterprises through producing and marketing green food wraps.. Additionally, since the world is looking for sustainable packaging, firms utilizing biodegradable wraps can achieve government incentives and competitiveness in the market.

4. Applications and Usability

The applications and purposes of beeswax-coated recycled paper wraps are multiple, and they are easy and eco-friendly alternatives to the traditional plastic wraps. Storage and preservation of food are among the primary applications. The wraps can wrap sandwiches, fruits, vegetables, cheese, and bowls, and the food keeps fresh and plastic is avoided. The natural antimicrobial property neem and turmeric also become more potent by inhibiting bacterial growth and spoilage. Apart from local consumption, wraps can have food packaging business applications as a green alternative to single-use plastics. Restaurants, bakeries, and organic food businesses can incorporate beeswax wraps as part of their packaging material, in line with consumer pressure for green and agricultural products, where biodegradable materials play a vital role. Apart from culinary use, these wraps could also end up in handmade and craft packaging, the better choice and environmentally friendly methods for businesses that deal in handcrafts, soap, or cosmetics. Water-proof in nature, they can also be employed to wrap files, books, and other sensitive documents from water. Uses of such wraps are more durable because they are simple to clean and reusable. In contrast to single-use plastic wraps, beeswax wraps are washed with cold water and mild soap, and reused multiple times before composting. This not only prevents wastage but also presents a cheap option to businesses and households looking for environmentally friendly substitutes.

Addressing these challenges through targeted research and innovation will enhance the feasibility and environmental benefits of beeswax-coated recycled paper wraps, paving the way for a sustainable alternative to plastic packaging.

5. Challenges and Future Research

Bee beeswax-coated recycled paper wrapping production also has some hurdles to be addressed in their performance as well as marketability. The most critical one is life span and durability, considering the wax coating, which wears out over time and, in the process, negatively affects food wrapping efficiency as well as food sealing performance.

Oil and water resistance are also issues since permeability of the paper results in its water absorbency, affecting the protection of the food. Adequate adhesion of recycled paper onto beeswax is also a technical issue since uneven coating results in flaking and loss of effectiveness. Additionally, standardization of the production process without compromising on environmentally friendly and economical production is required for its large-scale usage.

Consumer adoption and market penetration are also necessary, as people's awareness of the benefits and proper use of such wraps must be generated to enable the movement away from plastic-related alternatives. The other limitation is storage and handling since the wraps must be handled gently so as not to compromise wax and are not suitable for all food products, such as raw meat.Future research should aim at the development of material properties by means of the application of the incorporation of biopolymer reinforcements in an attempt to increase strength, flexibility, and barrier function.

More studies have to be conducted to achieve optimal food preservation and antimicrobial action by optimizing the neem and turmeric mixture. Biodegradation and composting tests will also provide insights into the environmental impact of these wraps and how they would degrade under various conditions.

The Comparison with other green products will give the data of how the bee's wax wraps compare with other biodegradable products. Additionally, willingness to pay and consumer buying behavior studies for eco-friendly packaging will inform product design and advertising strategy development. These issues having been addressed through co-research and development, profitability and the environmental impact of the beeswax-coated recycled paper wraps will be maximized.

II. METHODOLOGY

Collection and Preparation of Waste Paper

Material Selection**:** Collect waste paper (e.g., newspapers, office paper, or cardboard) free from plastic coatings or ink that may contain harmful chemicals. Soaking Process: The waste paper is soaked in water for 24 hours so as to soften the fibers and facilitate pulping

Pulping and Blending

Upon soaking, the softened paper is mixed with a mechanical blender to a fine pulp. Neem and Turmeric Addition: Natural antimicrobial neem (Azadirachta indica) and turmeric (Curcuma longa) are added to the pulp in order to increase microbial resistance. Adhesive Addition: A starch-based adhesive (e.g., cassava or cornstarch) is added to bind the fibers together and improve the strength and flexibility of the paper. The mixture is blended well in order to achieve uniform distribution of the additives.

Paper Sheet Formation and Drying

Filtration: Place the pulp on a clean and rinsed fine-mesh screen, or drain off excess water and roll it into thin sheets. Sheet Pressing: There is a roll or flat press to press flat the sheet.So that they are even in thickness. Drying Process: For drying out the excess moisture and setting the paper structure, sheets are dried in a tray dryer between 50 and 60°C.

Beeswax Coating Application

Beeswax Treatment: Beeswax will melt spontaneously at 65–75°C to be of smooth spreadable consistency. Coating Process: Used sheets of recycled paper, when dried, are coated by a thin film of molten beeswax by one of the following processes: Dipping: Paper is momentarily dipped into molten beeswax and pulled out to drain excess wax. Brushing: Brush is used to coat with an even layer of molten beeswax on the surface. Spraying: thin wax layer is sprayed on the paper for uniform coating. coated sheets are allowed to cool and harden at-room-temperature.

Cutting and Testing of Beeswax Wraps

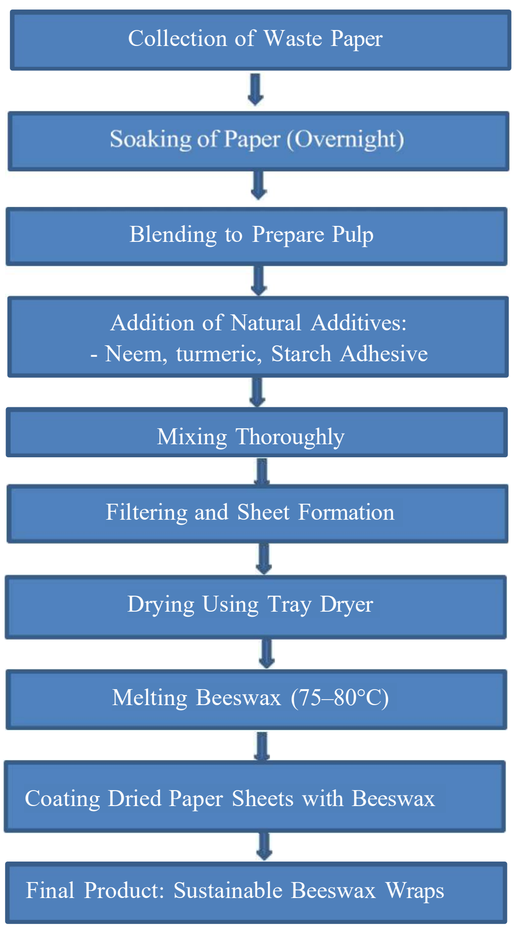
Once cooled, the beeswax-coated paper is cut into standard wrap sizes (e.g., 20×20 cm, 30×30 cm). The wraps undergo mechanical and physical property testing, including:

Tensile strength (to assess durability), Water and oil resistance (to evaluate barrier properties), Adhesion strength (to ensure wax remains intact), Biodegradability testing (to confirm environmental friendliness

Evaluation and Usability Testing The wraps are tested by wrapping food items such as fruits, vegetables, and bread. User feedback is collected regarding flexibility, adhesion, easy use.

Comparison with Conventional Plastic Wraps A comparative analysis is conducted between the developed wraps and commercial plastic wraps based on sustainability, functionality, and cost-effectiveness.

FLOW DIAGRAM



III. TESTING

1. WAX WEIGHT ADDED PER SAMPLE

The amount of wax applied to one sheet was measured in terms of weighing initial and final weights before and after applying the wax. An average sheet of paper required around 1.9 grams of beeswax Regular wax application avoided irregular coating on all samples, which is a trait required for distinguishing correct and reproducible results for strength test, water resistance, and flexibility. A graph displays the contribution ratio of wax put towards weight increase of all samples.

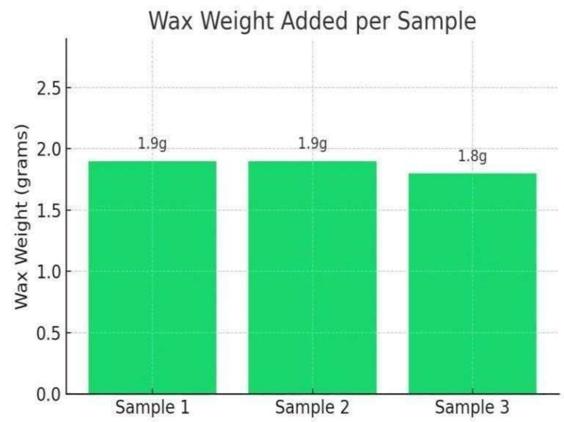


Fig: 1 Output Of Wax Weight Added Per Sample

2. PAPER WEIGHT TEST(BEFORE & AFTER WAXING)

To verify the impact of beeswax coating on sustainable paper wrap, a weight test was conducted. The initial weight of uncoated paper was approximately 3 grams as the standard. As soon as even application of both sides with beeswax occurred, weight increase was recorded as 4.9 grams corresponding to net increase of 1.9 grams by wax.

The rise verifies not just the quantity of wax utilized, also the efficiency of the coating process from the absorption and adhesion point of view. The added weight is proportionally related to improved functional properties such as water resistance, strength, and flexibility, verified by third-party testing. The respective graph (Figure X) shows a steep side-by-side plot, indicating the improvement in structure following waxing. The data also assists in the estimation of material cost per wrap and measuring wax distribution effectiveness in production.

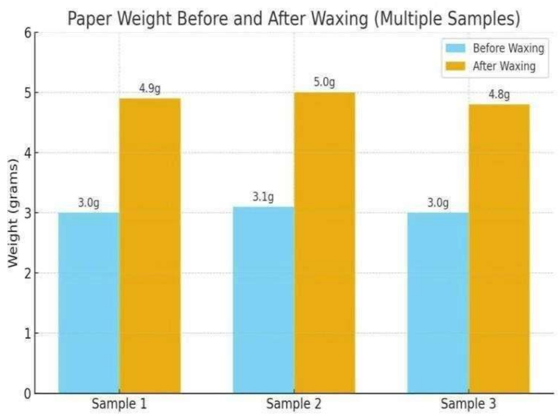


Fig: 2 Output Of Paper Weight Test

3. THERMAL HEAT RESISTANCE TEST

The heat resistance of waxed paper was then tested. The results, as shown in the graph, are that the material was stable up to 60°C. There was minor softening from 70°C to 80°C, and there was extensive degradation above 90°C. These results suggest that the wax covering offers average heat resistance, and the wraps are appropriate for food storage in room temperature or mildly warm products but not for high temperature use.

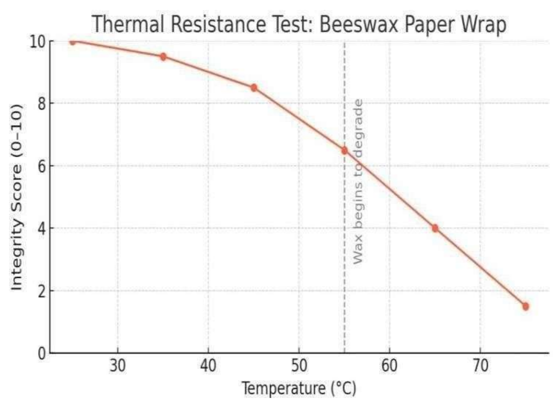


Fig: 3 Output Of Thermal Heat Resistance Test

4. STRENGTH TEST

The tensile strength of coated paper with wax was examined employing pressure continuously. The document was intact until 150 grams, and no breakage was observed. But when the pressure was 200 grams, the paper was beginning to tear, and further deteriorated with increased pressure. This shows that the coating of wax provides adequate strength to resist moderate pressure, and thereby the paper can be used for food wrapping. The above graph represents the breakage point.

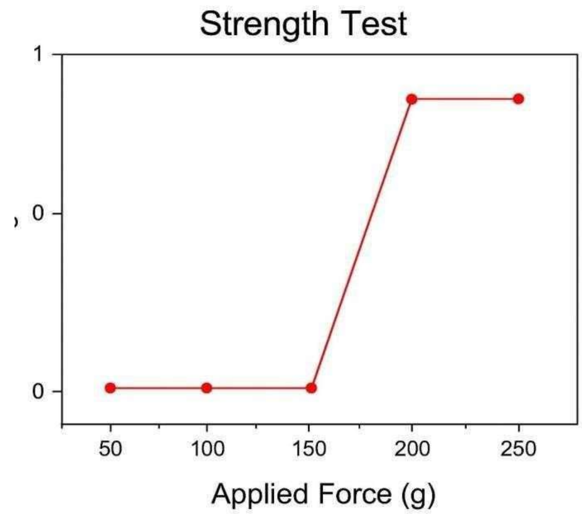


Fig: 4 Strength Test

5. FLEXIBILITY TEST (FOLD TEST)

Flexibility Test: The paper was rigid in shape and did not exhibit any cracks until the first 20 folds. After that, the cracks started to form and become more prominent as folding was repeated more. This shows that the paper has high flexibility and mechanical stress resistance.

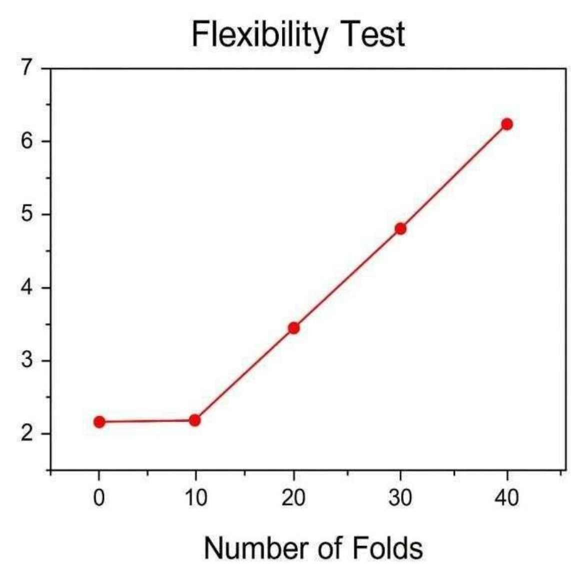


Fig: 5 Flexibility Test (Fold Test)

6 .WAX DURABILITY TEST

To test the stability of the beeswax coating under different environmental conditions, the samples were exposed to different levels of heat and humidity to simulate real-life usage. Under room temperature (25°C), the wax was stable with no signs of deterioration. Under moderate heat (60°C), there was slight softening, but the coating held its shape. Under high temperatures (above 80°C), the wax melted, which reduced its effectiveness. Under humid, the paper had somewhat swelled but still there remained some water resistance due to the wax. On dry conditions, the coating remained unbroken without any visible change. The test proves that the wax coating has a good functioning on dry and relatively hot conditions, and so it is ideally suited to surround dry or little warm food. Its functioning will remain poor under higher temperatures or humidity, although. which should be considered for purposes of application.

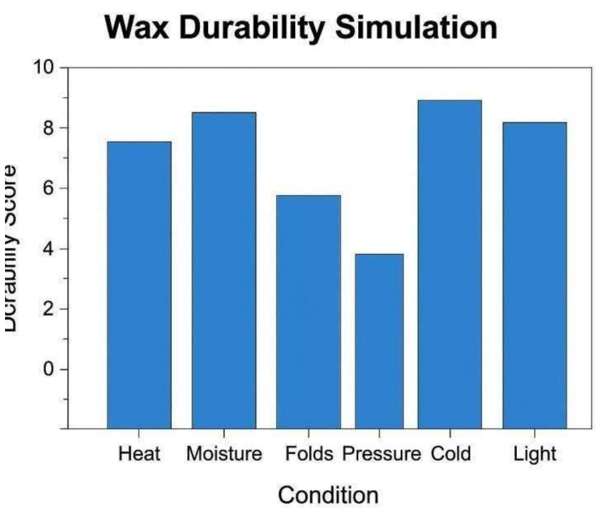


Fig: 6 Wax Durability Test

7. THICKNESS TEST

To ascertain the influence of coating beeswax on chemical makeup in recycled paper wraps, vernier caliper thickness test was carried out. Thin homemade paper and thick recycled paper were subjected to the test: with two papers for comparative observation in terms of interaction with coating.

The as-cast thickness of thin sheet was between 0.22 mm and 0.34 mm with an average value of 0.28 mm. The thicker paper, 0.60 mm to 0.82 mm, with a mean of 0.718 mm. Both were coated with beeswax that also gave the paper thickness, and that proved that the wax had been evenly applied and now became surface level. The thickness added not only conceals the added weight but also proves the coating hardened and made the paper stiff.

The thicker coating will offer improved insulation, water-proofing, and greater mechanical strength—useful qualities in green food wraps. The find indicates that the beeswax forms a hard, dense, and uniform film on the recyclable paper that toughens the surface without becoming brittle. The find confirms that the coating toughens the paper to make it available as an eco-friendly, reusable food wrap.

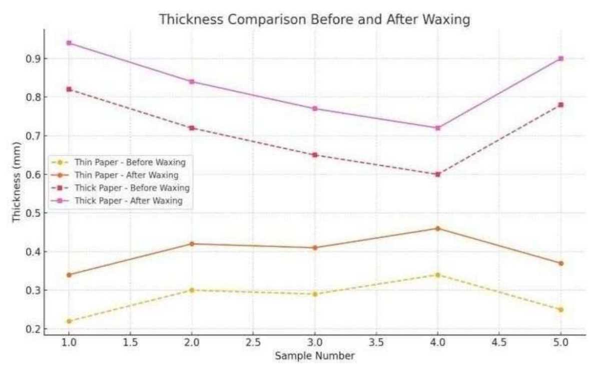


Fig: 7 Thickness Test

8. WATER ABSORPTION TEST

To determine the amount of protection offered by the beeswax coating against water, a water absorption test was done. All the water had been absorbed by the paper and had retained 100% of moisture added on initially. Holding progressively decreased with increase in time. At 3 minutes, holding dropped to 80%, then further to 60% at 6 minutes. At 9 minutes, water holding dropped to a meagre 45%. had gone on, and at 12 minutes had fallen further to 28%. At 15 minutes, 15% of water was still not absorbed. The results show that beeswax coating really retards the absorption of water by creating a barrier that shields the surface. In comparison with uncoated paper, which had absorbed water right away and lost its form, This is a better paper for food packaging and other applications where protection from moisture is necessary.

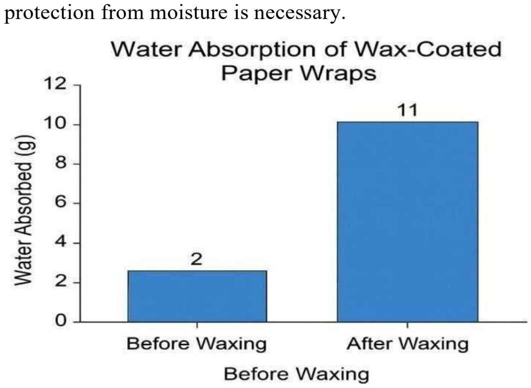


Fig.8 Water Absorption Test

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IV. PRODUCT OUTCOME

Fig 9. Bee Wax Coated Paper

V. RESULT AND DISCUSSION

This study focused on developing and evaluating sustainable wax-coated wraps made from recycled waste paper. Various tests were performed to assess their physical, mechanical, and functional properties after the application of beeswax.

Paper Formation and Wax Application

The waste paper was successfully pulped, filtered, and dried to form usable sheets. After the beeswax was applied to both sides, noticeable improvements were observed in the texture, strength, and overall appearance of the paper. The uncoated paper had an initial weight of 3.0 grams, which increased to 4.9 grams after waxing, demonstrating a consistent coating with an increase of 1.9 grams in weight.

Flexibility Test: The paper was rigid in shape and did not exhibit any cracks until the first 20 folds. After that, the cracks started to form and become more prominent as folding was repeated more. This shows that the paper has high flexibility and mechanical stress resistance.

Strength Test: The wax wraps were extremely strong enough to hold up to 150 grams of force applied without breaking. The breaking point for the structure was observed above 200 grams, validating the material strength for overall wrapping applications.

Water Resistance Test: The water absorption test revealed that firstly, the wax-coated paper was 100% water-resistant. The water absorption in 30 minutes was just 24%, which confirmed the high water-resistant property of the beeswax coating

Thermal Resistance The paper with wax coating retained its stability up to 60°C temperatures. It melted little in between 70–80°C, and above 90°C temperatures, it decomposed. This explains that the paper has medium thermal resistance, thereby suitable for handling hot foods along with room temperature use.

Wax Durability Test : The beeswax coating was in good condition when dry and not excessively warm. When high temperature or humidity were used, the coating started degrading, so wraps need to be stored in dry, repetitive use.

Overall Performance and Usability.

These results validate that the neem and turmeric-coated waste paper wraps are an eco-friendly and environmentally friendly choice as opposed to the traditional plastic wraps. Being reusable in nature, having antibacterial properties due to neem and turmeric, and being biodegradable, these are best suited to keep food. Physical and environmental testing proves these wraps are effective and reliable to use on daily.

VI. CONCLUSION

"Transforming waste paper into Sustainable Bees wax Wraps" is the eco-friendly, modern solution to both the biggest issues of wastage of paper and plastic. With wastepaper processing to recyclability as food wraps from entirely natural sources like neem, turmeric, and a starch adhesive the research study developed a product not only being eco-friendly in nature but also edible in nature.

Beeswax coating the outside of reusable paper was the key to success—a distinction of more strength, flexibility, and water resistance to the material. The wraps were recyclable, compostable, and lasted as long or even longer than disposable plastic wraps.

The project can implement waste minimization and sustainability objectives to reduce landfill waste and make circular material usage possible. Employment of renewable and natural inputs confers the wraps with a positive environmental impact as well as a flawless substitute for synthetic packaging material.

VII. REFERENCES

[1] Bhardwaj, Aastha, Nitya Sharma, Tanweer Alam, Vasudha Sharma, J. K. Sahu, Hinna Hamid, Vasudha Bansal, and Mohammad Sarwar Alam. "Development and characterization of chitosan and beeswax–chitosan coated biodegradable corn husk and sugarcane bagasse-based cellulose paper." Waste and Biomass Valorization 14, no. 5 (2023): 1625-1636.

[2] Chungsiriporn, Juntima, Piyaporn Khunthongkaew, Yutthawee Wongnoipla, Arrisa Sopajarn, Seppo Karrila, and Jutarut Iewkittayakorn. "Fibrous packaging paper made of oil palm fiber with beeswax-chitosan solution to improve water resistance." Industrial Crops and Products 177 (2022): 114541.

[3] Jahangiri, Fatemeh, Amar K. Mohanty, and Manjusri Misra. "Sustainable biodegradable coatings for food packaging: Challenges

and opportunities." Green Chemistry (2024).

[4] Duguma, Haile Tesfaye, Purva Khule, Aidan McArdle, Korey Fennell, and Eva Almenar. "Turning agricultural waste into packages for food: A literature review from origin to end-of-life." Food Packaging and Shelf Life 40 (2023): 101166
.

[5] Fetner, Hannah, and Shelie A. Miller. "Environmental payback periods of reusable alternatives to single-use plastic kitchenware products." The International Journal of Life Cycle Assessment 26 (2021): 1521-1537.

[6] Nair, SuryaSasikumar, Joanna Trafiałek, and Wojciech Kolanowski. "Edible packaging: a technological update for the sustainable future of the food industry." Applied Sciences 13, no. 14 (2023): 8234.

[7] Hamed, Imen, Anita Nordeng Jakobsen, and Jørgen Lerfall. "Sustainable edible packaging systems based on active compounds from food processing byproducts: A review." Comprehensive Reviews in Food Science and Food Safety 21, no. 1 (2022): 198-226.

[8] Kundungal, Harsha, Radhakrishnan Amal, and Suja Purushothaman Devipriya. "Nature’s Solution to Degrade Long-Chain Hydrocarbons: A Life Cycle Study of Beeswax and Plastic-Eating Insect Larvae." Journal of Polymers and the Environment 33, no. 1 (2025): 483-496.

[9] Zhang, Peixuan. "Analysis of the visual language of design of sustainable packaging manufactured from biomaterials." Journal of Print and Media Technology Research 12, no. 3 (2023): 139-146.

[10] Amjad, Fatima. "Design and Development of Eco-friendly Packaging System Utilizing Lignin Based Hydrogel Coated Biodegradable Paper." PhD diss., Chemistry Department COMSATS university Islamabad Lahore Campus, 2024.

[11] Versino, Florencia, Florencia Ortega, Yuliana Monroy, Sandra Rivero, Olivia Valeria López, and María Alejandra García. "Sustainable and bio-based food packaging: A review on past and current design innovations." Foods 12, no. 5 (2023): 1057.

[12] Perera, Kalpani Y., Amit K. Jaiswal, and Swarna Jaiswal. "Biopolymer-based sustainable food packaging materials: challenges, solutions, and applications." Foods 12, no. 12 (2023): 2422.

[13] Nidhi, Mr Chaitanya, Ms Alka Jaiswal, and Mr Ramesh Singh. "Addressing the Paradigm of “Zero Waste” for Attaining Sustainability in Indian Context/Scenario." The Institution of Engineers (India): 18.

[14] Siracusa, Valentina, and Marco D. Rosa. "Sustainable packaging." In Sustainable food systems from agriculture to industry, pp. 275-307. Academic Press, 2018.

[15] Zhang, Weiwei, Huining Xiao, and Liying Qian. "Beeswax–chitosan emulsion coated paper with enhanced water vapor barrier efficiency." Applied Surface Science 300 (2014): 80-85